5

# RELATIONSHIPS BETWEEN THE MITCHELLIAN, CHELTENHAMIAN AND KALIMNAN STAGES IN THE AUSTRALIAN TERTIARY

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## Abstract

Stratigraphic work in the Lakes Entrance area has established the existence and relationships of 5 shell beds, each with a fairly distinctive molluscan assemblage, in the complete Upper Miocene-Lower Pliocene sequence. The major elements of each assemblage are listed, with the exception of the second oldest, from which no specimens were available. A brief treatment of the rock units is followed by an historical discussion of the definition and usage of the Mitchellian, Cheltenhamian and Kalimnan Stages. On the basis of comparison of the fauna from the type section of the Cheltenhamian with those of the shell beds in the Gippsland Basin sequence, the stages are clarified in their relationships and redefined. Finally, the position of the Mio-Pliocene boundary in the local sequence is discussed.


## Introduction

Since Singleton (1941) introduced the Cheltenhamian and Crespin (1943) introduced the Mitchellian, both as immediately pre-Kalimnan, Upper Miocene local stages, there has been confusion about the relationships of the three stages. As yet, foraminifera have not proved very helpful in solving the problem, mainly due to paucity of pelagic forms in the Gippsland Basin (Carter 1959) from which both the Mitchellian and Kalimnan are defined. The type locality of the Cheltenhamian Stage is in the adjacent Port Phillip Basin. Fortunately, molluscan faunas are not scarce and they show a fair degree of change during the critical period of time. The situation is complicated by possible slight geographical differentiation between the two basins but it is not sufficient to cause any major problems.

The Australian Tertiary stages are primarily molluscan stages but their limits in terms of assemblages are at present rather vague. For this reason, in the present work, attention has been concentrated on a sequence of shell beds. Detailed stratigraphic work has been found necessary to establish their relationships and where redefinition has been found necessary these shell beds and their contained faunas have been used for stage limits.

Frequently in the past workers have not given stratigraphic sections and this has led not only to difficulty in the re-location of collected levels but also to loss of accuracy in the definition of both rock and time-rock units. It is hoped that the sections described will be useful as a basis for further work.

The conclusions elaborated upon in this paper were suggested during stratigraphic and petrological work on Tertiary sediments along the N. boundary of the Gippsland Basin. In the faunal lists which are appended the species have been identified as accurately as possible but a detailed palaeontological review has not been attempted. The information contained is made available at the present time as it seems unlikely that there will be opportunity to consolidate this work for several years.

The area about Lakes Entrance in the Parishes of Colquhoun, Colquhoun North


Fig. 1—Locality diagram of the Lakes Entrance area showing the position of measured sections.

and Bumberrah have been mapped by the Geological Survey of Victoria. A geological map (1″ ≡ 1 mile) and parish plans of the Bairnsdale area are also available.

## Descriptions of Sections

Some excellent sections of the upper part of the marine Tertiary sequence are exposed in the Lakes Entrance area. The distinctive feature of most of these is the ease of correlation between them. The only detailed descriptive section previously available from this area is given by Singleton (1941, p. 40) of strata at Jemmy's Point. It has been adopted here with modifications and additions. Beds (a) to (i) are the same as those of Singleton with modifications, and may be seen in the road cutting and rather poor cliff sections just on the N. side of the bridge over North Arm. Minor landslips make continuation of section beyond bed (i) difficult.

For this reason and in order to make the section more detailed, beds (j) onward do not correspond to those of Singleton's section. They have been measured from a point 20 yds W. of the most westerly exposure of the upper shell bed (h) which, as Singleton has noted, thins to the W. The 3″ sand bed appears to correspond with Singleton's bed (j) (8″ carbonaceous layers in fine sandstone) which is clearly exposed at the most westerly limit of the upper shell bed. Base level is about 2′ above high water mark.

### 1. Jemmy's Point:

| Bed | Thickness | Description |
|---|---|---|
| (p) | 120′ | Coarse clayey sands and fine gravels with sporadic pebbles and with varying degrees of ferruginization. A few horizons show steep cross-bedding. |
| (o) | ½″ | Brown richly carbonaceous and micaceous siltstone with occasional sandy and clayey burrows and lenses. |
| (n) | 6″ | Rather more poorly bedded than (m), yellow fine sand with conspicuous layers of mica. |
| (m) | 8″ | Thin bedded yellow silty sands with brown carbonaceous layers. |
| (l) | 1′ 6″ | Brown and grey streaked and mottled sands with grey clay streaks and burrow fillings grading up into poorly bedded pale yellow sands. |
| (k) | 6″ | Grey silt with plant fragments and burrows ½″ diameter with sandy brown infillings. |
| (j) | 3″ | Pale yellow bedded sand with carbonaceous streaks. |
| (i) | 3′ | Grey calcareous silty sand with a much lower shelly content than bed (h). Rich in black carbonaceous fragments. |
| (h) | 1′ | Upper shell bed, a richly shelly silty sand with carbonaceous fragments; irregular in thickness and thinning to the W. 2″ pebble band about 8″-10″ above base where found. |
| (g) | 3′ 6″ | Fine friable sandy calcarenite with long low-angle cross-bedded units in places, especially near the top tending to be cemented into tough, laminated calcarenite bands. |
| (f) | 11′ | Fawn calcareous silty sand with calcareous concretionary bands. |
| (e) | 4″ | Discontinuous tough calcareous sandstone. |
| (d) | 13′ | Fawn calcareous silty sand with irregular development of calcareous nodules. |
| (c) | 2′ | Lower shell bed, calcareous silty sand with *Eucrassatella*. |
| (b) | 2′ 6″ | Fine calcareous silty sand with calcareous concretions and a few *Turritella* near top. |
| (a) | 3′ 6″ | Fine silty sand. |

Singleton's pebble bed (k) is not visible at the present time but another 4″ discontinuous bed, 7′ above the top of bed (g) was found, as well as occasional pebbles from the Upper Shell Bed (h). The lower part of the Jemmy's Point section is better studied in the small vertical cliff, 40 yds E. of Kalimna Jetty where the base level is sea level at high tide.

2. E. of Kalimna Jetty:

| Bed | Thickness | Description |
|---|---|---|
| (f) | 1′ 6″ | Calcareous silty sand with numerous worn fragmentary mollusca. Large *Eucrassatella* conspicuous. |
| (e) | 2′ 3″ | Calcareous silty sand with a few complete valves of *Anomia* and other molluscan fragments. Similar to bed (c). |
| (d) | 6″ | Discontinuous coquina with worn molluscan fragments of *Eucrassatella*. |
| (c) | 6′ 6″ | Fawnish silt with indistinct structural mottling and with a few large (1″) burrows themselves mottled internally. Some well preserved and many fragmentary mollusca in lower part. Small carbonaceous fragments present. |
| (b) | 3″ | Coquina with broken and worn shell fragments. |
| (a) | 3′ 3″ | Grey and orange clayey sand with structural mottling. |

About 3 m. NNW. of Jemmy's Point, a low road cutting on the W. side of Mississippi Cr., which is the main continuation of North Arm, shows the following section:—

3. Mississippi Cr. Road Cutting:

| Bed | Thickness | Description |
|---|---|---|
| (d) | 5′ | Pale fawn? wind blown sand, poorly sorted near base with pebbles. |
| (c) | 33′ | Brown micaceous clayey sand, rather well sorted coarser fraction and containing no pebbles. Contains some structural mottling—grey clay lenses and nests near base. |
| | 6′ | Covered interval. |
| (b) | 6′ | Fine well sorted friable sandy calcarenite. Cross bedding, if present, cannot be observed because of poor exposure. A little cementation present at top of bed. |
| (a) | 30′ | Fawn calcareous silty sand, fairly rich in mollusca but superficially weathered and no structures are evident. Contains small black carbonaceous fragments which increase in proportion up to centre of bed, then decrease. |

Although this section is very poorly exposed, similarities between the beds here and at Jemmy's Point are immediately obvious. The basal bed (a) here corresponds to beds (a) to (f) at Jemmy's Point. Likewise, bed (b) corresponds to (g) and the covered interval occurs where the Upper Shell Bed might have been expected. The overlying brown micaceous clayey sand is similar in appearance to the lower part of (p). Due to the 6′ covered interval in the critical part of the sequence it is not possible to compare the sections more closely. There can be little doubt however that the approximate correlation suggested is correct.

The tramway track which extended from the Colquhoun Granite Quarry to North Arm along Mississippi Cr. has now mainly been removed and the low cuttings along the track, which furnished good suites of perfectly preserved mollusca in the past, are now overgrown with dense scrub. Limestone and fossiliferous ferruginous sandstone have been traced some hundreds of yards upstream from the old Colquhoun Quarry. Just upstream from the quarry and on the E. side of the creek (861391 Bairnsdale Military Map reference), at an elevation of about 180′ above sea level, an interesting section occurs in which kaolinized granite is overlain by polyzoal limestone with abundant *Spondylus* and also *Hinnites, Clypeaster, Serripecten* and *Ostraea*. In hand specimen it appears to contain no coarse sand or gravel thereby comparing with the limestone at Bairnsdale. It is overlain by fossiliferous ferruginous gravelly sand with poor casts and moulds of mollusca—*Spondylus, Cucullaea, Antigona, Conus, Chlamys,* etc.

Although the fossils do not suggest the presence of any important disconformity between the two beds, the presence nearby of ferruginous gravelly beds at the same level as the limestone, but without gravel, indicates that some break in deposition did occur rather than the irregular junction being due to weathering. The ferruginization has in most cases proceeded to gleying with strong development of grey and brown mottling. The gravelly component consists mainly of rounded quartz granules. The marine beds are overlain by cobble gravels with fossil silicified wood, the junction being strongly disconformable.

About 6 m. easterly of Jemmy's Point another good section is exposed in the sea cliff at Red Bluff. The section selected for description is situated 3 ch. W. of the Point. Base level is high water mark.

4. Red Bluff:

| Bed | Thickness | Description |
|---|---|---|
| (s) | 7′ | Poorly bedded micaceous sands basally deformed by load casts. |
| (r) | 2″ | Clayey gravel with pebbles up to 2″ long, symmetrically pinched up into overlying sand in places up to a height of 1′. |
| (q) | 2″ | Silt with sandy lenses. |
| (p) | 2″ | Discontinuous gravel lenses. |
| (o) | 1′ | Poorly bedded brown silts and grey clays. |
| (n) | 5″ | Grey sand with wavy ferruginous and carbonaceous streaks with lenses and more or less continuous thin layers of grey clay. |
| (m) | 3″ | Grey silt. |
| (l) | 1″ | Grey clay with brown streaks and wavy base due to sand lenses below and differential compaction. |
| (k) | 3″ | Average thickness of coarse poorly sorted sand, in discontinuous lenses up to 6″ thick. Coarser material at base (with occasional pebbles) grades up into finer sand above. |
| (j) | 13′ | Micaceous sands like bed (i) but without cementation horizons. |
| (i) | 13′ | Sands, cross bedded at low angle, cemented along frequent favoured cross bed sets. Occasional lenses, thick with fossil shells are present, the fossils now as casts and moulds. Rarely these lenses contain pebbles also. |
| (h) | 2″ | Calcarenite band. |
| (g) | 1′ | Light grey sandy silt, richly mottled with brown sandy burrows and grey clayey nests and lenses. |
| (f) | 5″ | Tough calcareous siltstones band, rather irregular in thickness, with traces of carbonized wood fragments. |
| (e) | 1′ | Light grey silty sand with occasional brown sandy mottles and other indistinct mottling, a few mollusca and black carbonaceous fragments. |
| (d) | 1′ | Homogeneous dark grey sandy silt, rich in woody fragments and mollusca (mainly pelecypods, some complete valves but mainly fragments). |
| (c) | 5′ 6″ | Fawn calcareous silty sand with decomposed shells structurally mottled with lenses and streaks of grey clay. Upper part of bed with interformational folding structures in calcareous sand. |
| (b) | 2′ | Fawn shelly calcareous silty sand with numerous fragments of pelecypods and some complete valves structurally mottled with grey clay streaks. |
| (a) | 9″ | Fawn silty sand structurally mottled with grey clay streaks. |
| | 5′ | Beach sand, covered interval. |

The correlations suggested are bed (i) and probably (j) of this section with (g) of Jemmy's Point; and beds (k) to (r) with (j) to (o) of Jemmy's Point.

A better correlation can be made between the sequence at Jemmy's Point and road cuttings on Princes Highway where Bunga Cr. is crossed. Sections have been measured on both sides of the creek because of slight differences and also because they are to some extent complementary.

5. Bunga Cr. Road Cutting (S. Side):

| Bed | Thickness | Description |
|---|---|---|
| (f) | 10′ | Sandy finely laminated ? lagoonal sediments which cannot be reached to study in detail. |
| (e) | 4′ 6″ | Shelly calcareous sandy silt with much lower shelly content than bed (d). Rich with carbonized wood fragments. Sandy filled burrows rare. |
| (d) | 1″–6″ | Thin discontinuous irregular compact calcareous siltstone band with casts and moulds of mollusca. |
| (c) | 4′–6′ | Shelly calcareous silty sand developed on the irregular surface of bed (b). Occasional pebbles present in lowest foot above base. |
| (b) | 6″–1′ | Irregular and discontinuous development of tough limestone, moulds and casts of mollusca absent. |
| (a) | 22′ | Fawn calcareous silty sand with several horizons of interformational folding structures in calcareous sand. In the upper part these give way to thin bedded fine friable sandy calcarenite with long low cross bedding structures. In one place these show a small structure at the top. |
| | 43′ | Covered interval to bridge level. |

6. Bunga Cr. Road Cutting (N. Side):

| Bed | Thickness | Description |
|---|---|---|
| (k) | 18′ | Poorly bedded almost structureless fine well sorted micaceous sands with occasional discontinuous calcareous cemented bands containing casts and moulds of shell fragments. Some traces of low angle cross-bedding are developing in the tough bands. |
| (j) | 4′ 6″ | Shelly calcareous sandy silt with much lower shelly content than bed (g), but rich with carbonized wood fragments. Brown sandy filled burrow structures in upper foot, also grey clay nests and lenses. |
| (i) | 6″ | Discontinuous compact calcareous siltstone, with carbonaceous fragments and casts and moulds of mollusca. |
| (h) | 3′ | Fawn calcareous sandy silt with decomposed shell fragments and particles of carbonaceous material. |
| (g) | 1′ 6″ | Shelly calcareous silty sand, rich in molluscan specimens but not in species. Occasional rounded pebbles in lower 6″. Interrupted by sandy interformational folding units. |
| (f) | 6″–1′ | Discontinuous tough limestone band. |
| (e) | 33′ | Fawn marl with poorly developed colour and structural mottling. Mollusca mainly decomposed but some well preserved specimens occur near the base. Upper part with horizons of interformational folding structures and horizons of irregular cementation. |
| (d) | 6″ | Shelly calcareous silt, very rich in broken and abraded molluscan shells, including many large broken *Eucrassatella*. |
| (c) | 11′ 6″ | Fawnish calcareous silt with poor colour and structural mottling. Shells few, mainly decomposed. |
| (b) | 7′ 6″ | Grey calcareous shelly sandy silt with brown colour mottling, very rich in both species and specimens. *Turritella* of large size near top of bed. |
| (a) | 18′ | Brown and grey colour mottled calcareous silty sands, the mottling developing to different extent from place to place. Fossiliferous all through with occasional shelly bands rich in *Turritella* and *Venericardia*. A little sandy and clayey structural mottling present. |
| | 15′ | Covered interval. |

Base level for both sections is bridge level, approximately 10′ above sea level. In both sections the Upper Shell Bed (h) of Jemmy's Point can be readily matched. It corresponds to beds (g) and (h) (N. side) and (c) (S. side) if the less fossiliferous overlying portion is included. The correspondence is not only in general but also in some detail.

The Upper Shell Bed in the Jemmy's Point section has few common species but they are present in large numbers. All shells are robust and the more delicate genera are absent. Both fragments and complete shells are present generally with good preservation. Black carbonaceous fragments are common, bedding is absent. The most surprising feature is the inclusion of pebbles, usually in a thin discontinuous band in the middle of the bed. All these features are to be found in the equivalent beds at Bunga Cr. despite the fact that Bunga Cr. is more than 4 m. distant from Jemmy's Point.

Other beds can also be matched with some confidence. The grey calcareous silty sand (i) of Jemmy's Point corresponds in lithological detail to bed (j) (N. side) and bed (e) (S. side). The non-calcareous beds (j)-(o) at Jemmy's Point can only be equated to bed (f) at the top of the S. cutting. On the N. side of the creek the calcareous beds do not give way to a variable non-calcareous sequence but continue to contain bands with marine fossils. This has important palaeogeographical implications.

Beneath the Upper Shell Bed in all three sections, the distinctive fine friable calcarenite occurs with cementation of some of its long low cross bedded units, especially near the top. Within this bed and below it in both Bunga Cr. sections, but not at Jemmy's Point, interformational folding structures occur (compare Emery 1950). That their range in time of occurrence increases shoreward is shown by the fact that some distinct ones actually interrupt the Upper Shell Bed in the N. cutting but not in the S. cutting. These structures are identical to those in the lower part of the Red Bluff sequence. In a general way, they seem to be useful in correlation.

The best argument for the correlations suggested is that the beds distinguished occur in the same sequence from place to place. It seems likely that if existing bore records were more detailed it would be possible to make accurate sedimentary and palaeogeographical reconstruction of the whole Lakes Entrance district.

Continuing N. along Princes Highway, we find that road cuttings over Toorloo Arm expose sediments of the older parts of the sequence. The section given is composite, using data from both N. and S. sides of the bridge. On the S. side *Serripecten, Spondylus* and *Chlamys antiaustralis* were observed at 57′-62′ above water level which is approximately sea level. On the N. side *Chlamys antiaustralis* was noted from 82′ above water level. At 98′ above water level on the S. side, a 6″ pebble gravel occurs in the soil and weathered sediment. It is almost horizontal, cutting across soil horizons, thereby reflecting the character of the original sediment. Bed (d), present only on the N. side, overlies beds of the marine sequence unconformably.

7. Toorloo Arm Road Cuttings:

| Bed | Thickness | Description |
|---|---|---|
| (d) | 56′ | Poorly sorted brown, red and grey mottled pebbly sands. |
| (c) | 18′ | Sands with bands of calcareous sandstone and occasional *Arachnoides*. |
| | 52′ | Covered interval. |
| (b) | 39′ | Creamy glauconitic calcareous silt weathering to a brownish ferruginous silt. Calcitic mollusca present. Gradual transition from bed below. |
| (a) | 45′ | Yellow poorly bedded uncemented polyzoal limestone, upper part rich in calcitic mollusca. *Clypeaster* present down to water level. |

A fuller sequence of the limestone is exposed in the track leading down to McRae's Kiln, Toorloo Arm which is situated 1 m. NW. of the highway bridge over Toorloo Arm.

8. McRae's Kiln, Toorloo Arm:

| Bed | Thickness | Description |
|---|---|---|
| (c) | 4′ | Brown and yellow polyzoal limestone with rather more ferruginous material than bed (b). Some sand grains. (Very occasional grains of sand are to be found in the upper part of bed (b) but none were observed in (a)). |
| (b) | 28′ | Yellow poorly bedded polyzoal limestone, thick with complete *Spondylus, Clypeaster* etc with finer polyzoal limestone developed in places, in others the shelly horizons develop into a coquinoid limestone. |
| (a) | 40′ | Poorly bedded creamy fine polyzoal limestone, rather greyish near base due to higher silt and clay fraction. The few bands of small mollusca present, not so thickly populated as in (b). No *Clypeaster*. |

The base of the measured section is 21′ above lake level which is close to sea level. Beds (a) and (b) form distinct units in the field. Bed (c) appears to be the weathered upper part of (b). The lowest limestone exposed in the Princes Highway sections over Toorloo Arm (bed (a), section 7) is similar in lithology to bed (b) of this section.

On Nowa Nowa Arm (at 053378, Hartland Military Map reference), about 5 m. to the E. of McRae's Kiln, cliffs of poorly bedded limestone contain *Clypeaster, Spondylus, Ostraea, Anomia,* brachiopods, etc which again form a coquinoid limestone similar to bed (b).

The overall picture obtained is of very low southerly dipping Tertiary sediments warped up onto the flanks of the Palaeozoic highlands which fringe the basin to the N. Although the dip on the sediments is perhaps low enough to be considered as initial dip, the presence of the same molluscan assemblage in the top of the limestone formation above the Colquhoun granite quarry at an elevation of about 180′, as in the top of the same formation at about sea level further out into the basin, shows that the beds have attained their present attitude mainly by mild tectonic influence. The only place in the area where actual faulting in the Tertiaries has been observed is in the road cutting on the Princes Highway on the S. side of Bunga Cr. where a throw of 3′ or 4′ is evident.

Thus, because of the attitude of the beds and the presence of creeks, or lake arms, at or about sea level, which are crossed going northerly from Lakes Entrance, a fairly complete sequence is exposed.

## Descriptions of Rock Units

In this paper it is not proposed to discuss the rock units in any detail. (This will be done in the near future by Dr A. N. Carter.) However, since the formations are involved with the problem in hand, and since two new units are present in the area discussed, a brief outline of the sequence of rock units will be given in ascending order.

### Bairnsdale Limestone:

The Bairnsdale Limestone (Howitt 1874) is the oldest formation indicated in the measured sections. It is conveniently considered as composed of an upper shelly and lower dominantly polyzoal portion, as Crespin (1943) has already observed The McRae's Kiln section is probably the best surface section available for study. The two units are represented by beds (b) and (a) respectively. In the Toorloo Arm section bed (a) belongs to the upper shelly portion. It is also well exposed in cliffs along Nowa Nowa Arm, L. Tyers.

TAMBO RIVER FORMATION:

In 1949 Thomas and Baragwanath proposed a formal name for this unit which was left unnamed by Crespin (1943). Their term (Tambo Formation) was unfortunate because of possible confusion between it and the well known Tambo Formation of Queensland (Whitehouse 1926) and the Mt Tambo 'Series', N. of Bindi, Victoria (Gaskin 1943 and references).

In Boutakoff (1955) the name was changed to Tambo River Formation. In published accounts this rock unit has not been given a satisfactory description.

Following the Bairnsdale Limestone, a change in conditions resulted in an increase of terrigenous material to the area of sedimentation. The lithological change produced is most marked in a general shoreward direction where a gravelly facies is developed over a distance of at least 20 m. in the Bairnsdale area. It is not known from the Lakes Entrance area. Accompanying the increase of the terrigenous fraction is a corresponding increase in glauconite. Everywhere glauconite in various stages of oxidation to limonite is abundant.

Passing upwards in the formation, the terrigenous fraction gradually changes from more silty to more sandy. There is a corresponding change in the fauna from dominantly polyzoal to dominantly shelly (Crespin 1943, p. 30) and glauconite, so richly developed in the lower portions, begins to become rarer. The junction of the Tambo River Formation with the overlying Jemmy's Point Formation cannot be observed in surface section in the Lakes Entrance area. In the Toorloo Arm section, where it might have been expected, a covered interval entirely masks the relationship, but bed (b) must represent almost the entire thickness of Tambo River Formation.

Crespin recorded a sharp lithological break between the Mitchellian and Kalimnan strata (i.e. between the Tambo River Formation and the Jemmy's Point Formation), but wherever the writer has examined the formational boundary in the Bairnsdale area, the transition has been entirely gradual.

Evidence from outcrops can add little towards solving the problem of exact formational definition, but since a distinctive break is at least not always present, it is suggested that the boundary should be drawn arbitrarily at the horizon where the sand-sized fraction of the terrigenous component first exceeds a certain limit. Or it may be that the percentage glauconite used in much the same way is a better indicator. Before a limit is finally decided upon systematic study of sediments from representative bores needs to be undertaken.

JEMMY'S POINT FORMATION:

This formation was introduced by Crespin as the rock unit approximately equivalent to the rock-time unit of the Kalimnan Stage. The marine beds at Jemmy's Point were clearly meant to be the type of the formation. They have been described as shelly and otherwise calcareous silty sands and sandy calcarenite.

One of the most distinctive features of the formation, which does not seem to have been sufficiently commented upon, is its lithological variety. This is one reason why it is difficult to define, but it is also one of its most distinctive differences from all preceding formations. Especially in that part of the Jemmy's Point Formation exposed above sea level at the type locality, the fairly homogeneous character of previous formations is lost and burrows, cross bedding and other structures become common. For the first time normal bedding becomes well developed in places and distinct lithological units may be traced from place to place with some confidence.

These units, the Upper Shell Bed, the 'foraminiferal silt' of Singleton (1941) and others indicated in the descriptive section, almost attain the status of members but, until they are recognized from bores, no useful purpose would be served by adding to the list of named units.

At the type locality the marine beds give way to what are believed to be lagoonal beds, and the top of the Jemmy's Point Formation is bed (i) of Section 1. Similarly the top of the formation at Red Bluff and the S. side Bunga Cr. road cutting is represented by bed (j) (Section 4) and bed (e) (Section 5).

On the N. side of Bunga Cr. no lagoonal beds succeed the 'foraminiferal silt' of Singleton, their place being taken by micaceous calcareous sands, which are strongly cemented in certain horizons. These beds contain casts and moulds of well preserved marine mollusca. Because of their lithological similarity to the material of the inter-formational folding units, they are best included in the Jemmy's Point Formation. Similar remarks apply to bed (c), Section 7.

The upper 10′ or so of the Jemmy's Point Formation is high in mica content and the succeeding lagoonal beds have some laminae composed mainly of mica.

In areal extent the Jemmy's Point Formation is exposed in outcrop from Nungurner to Lakes Entrance and around North Arm and L. Bunga in cliffs. The formation is also exposed in numerous road cuttings in this area, the most important of these having been indicated in the descriptive section. In the Bairnsdale area the formation does not occur in typical development.

At the type section its thickness above sea level is 40′-45′ and below sea level similar beds seem to continue to 130′-140′. In the Bairnsdale area its thickness is much less, but in every case the marine beds are overlain by gravels with an important erosional interval.

NYERIMALANG FORMATION:

This name is proposed for what are believed to be lagoonal sediments which overlie the marine beds at Jemmy's Point, Bunga Cr. (S. side) and Red Bluff without important erosional interval. Sediments of this formation are distinguished from those of the Jemmy's Point Formation by absence of calcareous component.

Boutakoff (1955) recorded leaf beds at Nyerimalang (locality F/7, parish of Colquhoun) resting upon Jemmy's Point Formation and grading upward into the 'Haunted Hill Gravels'. These carbonaceous leaf beds, which are also considered to belong to the Nyerimalang Formation, actually immediately overlie more sandy beds typical of this formation at Jemmy's Point.

The sediments consist of sands, micaceous sands, carbonaceous silts and structurally mottled clayey sand. In the type section at Jemmy's Point only beds (j)-(o) inclusive belong to this formation. Its average thickness is only a few feet.

The relationship between this formation and overlying sands is transitional as noted by Boutakoff. The whole exposed sequence at Jemmy's Point has only negligible erosional intervals and environmental changes as evidenced by lithological changes were gradual.

EAGLE POINT SANDS:

For a thickness of sands with a distinct fluviatile size distribution, exposed in the lower part of the cliff section at Eagle Point, 17 m. W. of Lakes Entrance, the name Eagle Point Sands is here proposed. The section has been described by Dennant and Clark (1903). At this locality a thickness of cobble gravels overlies some 60′ of Eagle Point Sands with a strongly disconformable junction. The cobble gravels, which are clearly Chapman's (1918, 1926) 'Bairnsdale Gravels' or 'Torrent

Gravels' are currently (Boutakoff 1955) considered to belong to the Haunted Hill Gravels (Thomas and Baragwanath 1949).

The sands at Eagle Point are correlated with the sands which succeed the Nyerimalang Formation at Jemmy's Point. These sands show a similar size distribution in the middle and upper portions, but towards the base are more clayey.

The relationship of these coarse, poorly bedded sands with the folded, finely laminated lacustrine sandstone of the Lake Wellington Formation (Boutakoff 1955, 1958) in a more westerly part of the basin is not known.

## Time — Rock Units

It is proposed to deal with the stages historically in order to show how their usage has developed.

### Kalimnan

The first work of importance on the area was produced by Dennant (1891) who described results of a field collecting trip to Jemmy's Point, Lakes Entrance and the cliff sections a few miles W. of Jemmy's Point. In this paper a list of some 110 macrofossil species was given. The beds were aged as Miocene using Lyell's percentage method.

A paper followed in 1898, which outlined the results of further work, enabling the approximate N. boundary of 'Miocene' strata between L. Tyers and Bairnsdale to be established (Dennant and Clark 1898). Additions and corrections to the previous fossil list were given, many of the new records evidently being from L. Bunga and Ritches' on the Mississippi Cr., the stratigraphic positions of which are close to that of bed (b), Section 6 of the present paper. As will be shown later, the thickness of Jemmy's Point Formation in this area (Bunga Cr.) is close to that at Jemmy's Point. Without too much error it may therefore be assumed that bed (b), Section 6 is equivalent to an horizon 10′-15′ below sea level at Jemmy's Point, that is about 18′-23′ below the Lower Shell Bed (c).

These lists formed the basis of Dennant and Kitson's (1903) catalogue of Gippsland Lakes fossils.

Local stages were introduced by Hall and Pritchard (1902) in an attempt to reduce the confusion caused by the use of European terminology. The Kalimnan stage was proposed as follows:— 'Kalimnan—The beds at Jimmy's Point (= Jemmy's Point) near the mouth of the Gippsland Lakes, are near the township of Kalimna. They were referred to Older Pliocene by Sir F. McCoy and by Mr. Dennant to the Miocene.' Since that time the stage name Kalimnan has been widely used, workers evidently feeling that this was one of the most respectable of the local stages.

Thus, adhering strictly to the original definition, the Kalimnan fauna would be that in the cliffs above sea level at Jemmy's Point. It has been seen, however, that the faunal lists of Dennant and Clark (1898) and Dennant and Kitson (1903) were diluted by records from beds equivalent to below sea level at Jemmy's Point. This is probably also true of the list in Dennant (1891). Thus in actuality, when a Kalimnan age was assigned to a locality beyond the Lakes Entrance area, it was done on the basis of comparison with the gross fauna in beds above sea level and somewhat below sea level at Jemmy's Point.

By 1932 Chapman and Crespin were clearly using the Kalimnan in an even more extended sense, namely, in the sense of the fauna of the Jemmy's Point Formation. In fact, correlation was probably made not so much on faunas as on lithology, a practical expedient which was well founded, for even at the present time it would be difficult to prove that the junction of the Tambo River Formation and Jemmy's Point Formation is diachronous, except close to the old shoreline. The new usage of the Kalimnan was made possible by the additional data from oil bores.

Chapman and Crespin divided the Kalimnan into three zones—C1, C2 and C3—about a central shelly marker bed C2, which is usually about 10′ thick. Near Jemmy's Point, on the beach of North Arm, NW. approach to the bridge, Lakes Entrance, in No. 1 Government Bore (No. 3 Lakes Entrance), this bed was first met with at 90′ (surface level 9′). The 'Kalimnan', which in fact in this case means Jemmy's Point Formation, was listed as continuing down to 140′. Unfortunately, the marker bed C2 is not known to the writer to occur above sea level in exposure and a faunal list has never been published from it.

Singleton (1941, p. 42) consolidated this usage by precise definition and reference to the measured section along the highway at Jemmy's Point. 'The Kalimnan may be defined as the interval of time represented by the deposition of the sandy marls and sandstones constituting beds (a)-(i) in the above sequence at Jemmy's Point, Kalimna, together with similar beds down to 131′ below sea level, proved by boring at this locality, as well as those represented in the preceding by non-deposition or erosion.' Beds (a)-(i) in Singleton's section also correspond to beds (a) to (i) in the writer's section.

In the beds above sea level Singleton distinguished two shell beds, upper and lower, and listed the more prominent mollusca of each.

Crespin (1943) adopted Singleton's usage, but referred to Singleton's two shell beds as zones (p. 30). 'Singleton (1941) has described the section (Jemmy's Point) in which he distinguishes an upper and a lower zone.' Later (p. 38) in a list of outcrops from the lower zone, she grouped Jemmy's Point (base of section) with others, such as Princes Highway, E. of L. Bunga and along Tram Track, Mississippi Cr., which occur in a stratigraphic position inferior to that of the Lower Shell Bed, Jemmy's Point.

Thus the lower zone was extended to include the fauna not only from the Lower Shell Bed, but down, apparently to the base of the Kalimnan.

The comprehensive list of macrofossils given in that Bulletin unfortunately contains fossils from both of Crespin's zones and includes fossils from beds equivalent to both above and below sea level at Jemmy's Point.

## Cheltenhamian

The marine beds at Beaumaris (near Cheltenham), Port Phillip Bay, are disappointing because of the state of preservation of the contained molluscan species, but due to proximity to Melbourne have been the subject of a good deal of collecting from the end of last century till the present time. Literature references, therefore, are numerous.

More recent stratigraphic accounts are given by Singleton (1941) and Gill (1957). Essentially, a calcareous sandy silt of Bairnsdalian age, as judged by the *Cucullaea* it contains, is overlain by a phosphatic nodule bed, a few inches in thickness, which in turn is overlain by a series of calcareous sands and ferruginous sandstones. The unfossiliferous ferruginous sandstones at the top of the section at the Beaumaris boatsheds, which were excluded by Singleton from the type thickness of Cheltenhamian, raise some interesting problems which need not concern us here (Gill 1957, p. 174).

The stage was introduced by Singleton (p. 35): 'The Cheltenhamian may be defined as the interval of time represented by the deposition of the nodule bed and of the overlying sandstones constituting beds (a) and (b) in the above sequence at Beaumaris, near Cheltenham, as well as those represented therein by non-deposition or erosion.' Beds (a) and (b) refer to one of the two sections measured by Singleton in which 22′ of Cheltenhamian beds are recorded. Gill 1957, p. 178, Fig. 15, referring to the other section, makes the thickness up to about 35′ by including the bed above, but this was evidently not Singleton's intention.

Of the available lists of macrofossils (Pritchard (1892), Hall and Pritchard (1897) and Dennant and Kitson (1903), only Hall and Pritchard (1897) give lists free of fossils from below the nodule bed. The writer feels, without much fear of error, that the mollusca in the latter list may be taken as coming from above the nodule bed. Indeed the majority of mollusca collected from Beaumaris come from Singleton's bed (a), NE. of the boatshed and a few feet above it. This means that the Cheltenhamian molluscan fauna has been principally obtained from 5′ or 6′ of calcareous sands near the base of the type thickness of sediment. None of the characteristic mollusca listed by Singleton is restricted to the stage.

## Mitchellian

The Mitchellian Stage was introduced by Crespin (1943, p. 25) for 'passage beds between the Balcombian and Kalimnan Stages', noting that 'the sediments consist of marls containing a mixed assemblage of Balcombian and Kalimnan species of foraminifera, bryozoa and mollusca, the characteristic fauna of the former stage dominating the basal portion and that of the latter the upper part'.

The Water Trust excavation near Bairnsdale was designated as the type section, although it was admitted that the full thickness of Mitchellian sediments was probably not completely present. In this section the junction between the Tambo River Formation and underlying Bairnsdale Limestone is visible. Just as the Kalimnan was eventually defined on a primarily lithological basis, so the Mitchellian was defined as a time-rock unit approximately equivalent to an unnamed transitional formation, which, as we have seen, was later named the Tambo River Formation.

Small lists of macrofossils and microfossils were presented for each of two beds in the lower portion of the section. Because of absence of a stratigraphic section in Crespin's work, the author has not been able to locate the collected levels with certainty, but it may be assumed that the lower one at least, which was collected (p. 26) from 'just above that containing large bivalves typical of the type locality for the Bairnsdale Substage', is representative of a very low horizon in the Mitchellian.

The list unfortunately contained no mollusca and the second sample from the lower portion contained only 12 species. A further list from 'beds representing the upper portion of the stage', but not from an accurately specified position contained 27 molluscan species.

Description of the type surface section was supplemented by a standard subsurface section, namely No. 11 Bore, Parish of Colquhoun. According to Crespin, the Mitchellian was met with at 195′, but we should note that this is the boundary between the Jemmy's Point and Tambo River Formations. An extensive list of microfossils and macrofossils was given from beds met with from 195′ to 238′. From 238′ down to 294′ fewer macrofossils were identified, but microfossils were increased.

No restricted zonal species were indicated, and the characteristic feature of the Mitchellian was evidently considered to be the presence of a mixed assemblage of Kalimnan and Balcombian (Bairnsdalian) species.

### Kalimnan-Mitchellian Faunas in the Gippsland Basin

It is desirable that some explanation of the appended fossil lists should be given. They have been prepared using the Chapple, Cudmore and Dennant collections in the National Museum of Victoria, Melbourne, supplemented by the writer's own field collections. The locations of all recorded specimens are entirely trustworthy. It should be realized that most of the species were described by Tate from the Grange Burn Coquina, Hamilton, Western Victoria, and combined geographical and stratigraphical differences make the Gippsland Basin equivalents in many cases subspecifically or specifically different. To solve this problem many species have been recorded by affinity. The same problem has been met by Ludbrook (1954) in her description of the mollusca of the Dry Creek Sands, Adelaide.

Many complex groups, such as the Turritellidae, Naticidae and Marginellidae are entirely absent, or are sparsely recorded in the lists, though it is probable that, if such groups were thoroughly examined, many excellent marker species would be found. The absence of a recorded species from any locality means that it is not present in any of the collections examined. Unrecorded species are not necessarily absent from any locality.

In the attached lists 3 fairly distinct 'Kalimnan' assemblages can be recognized. The lower one is represented by Bunga Cr. (Section 6, bed (b)) and Tramway Cutting, Mississippi Cr., but the exact stratigraphic position of the former only is known. The other 2 assemblages are from the Lower Shell Bed, Jemmy's Point, and from the Upper Shell Bed at Jemmy's Point and its equivalents (Bunga Cr., Section 5, bed (c) and Nyerimalang). The assemblage from Meringa Cr. is midway between the two lower assemblages, having otherwise restricted elements of both. So far as the stratigraphy of its occurrence is known, it is not at variance with this placing of the assemblage.

The other Gippsland fauna listed, that from Rosehill Farm on the Mitchell R. comes from the upper part of the Tambo River Formation and presumably therefore from the upper part of the Mitchellian. It is hoped that the stratigraphy of the Mitchell R. sequence will be described in the near future at which time the exact position of the shell bed will be indicated.

The relationship of Chapman and Crespin's marker bed C2 with the other shell beds needs to be clarified. At L. Bunga, about ¼ m. SE. of where the highway crosses Bunga Cr., Lakes Entrance Development Bore No. 1 was put down, surface level being 9′ above sea level. From the Bunga Cr. Road Cutting (Section 6), a total of about 98′ of sediments is recorded from below the top of the Upper Shell Bed to creek level which is not far above sea level. According to Chapman and Crespin (1932), 93′-111′ of Kalimnan sediments occur below sea level in this bore. Allowing for the more southerly position of the bore from the surface section, it is reasonable to assume that the thickness of 'Kalimnan' sediments at Bunga Cr. is within 10′-20′ of the thickness at Jemmy's Point.

Samples from the L. Bunga bore referred to above were only made available to Chapman and Crespin from 102′. Unfortunately the critical portion for our purpose was unsampled and the bore log (Mines Department, Victoria 1938, p. 24) is not detailed enough to be useful. However, if the marker bed C2, which Chapman and Crespin recorded from 90′-100′ below sea level at Jemmy's Point, is nearly as constant in its occurrence as these authors maintained, it would be expected at about 30′-40′ below sea level at the Bunga Cr. section. This bed would undoubtedly have another distinct assemblage.

We are thus left with 5 molluscan assemblages in the Upper Miocene-Lower Pliocene sequence. The writer's work on the Tertiaries along the N. boundary of the Gippsland Basin where erosional intervals may be expected to have developed, if anywhere, has convinced him that there is no appreciable break in the Upper Miocene-Lower Pliocene sequence. Although the Mitchellian and Kalimnan stages defined have no distinct faunal limits, it is clear that they must be continuous with one another without a break.

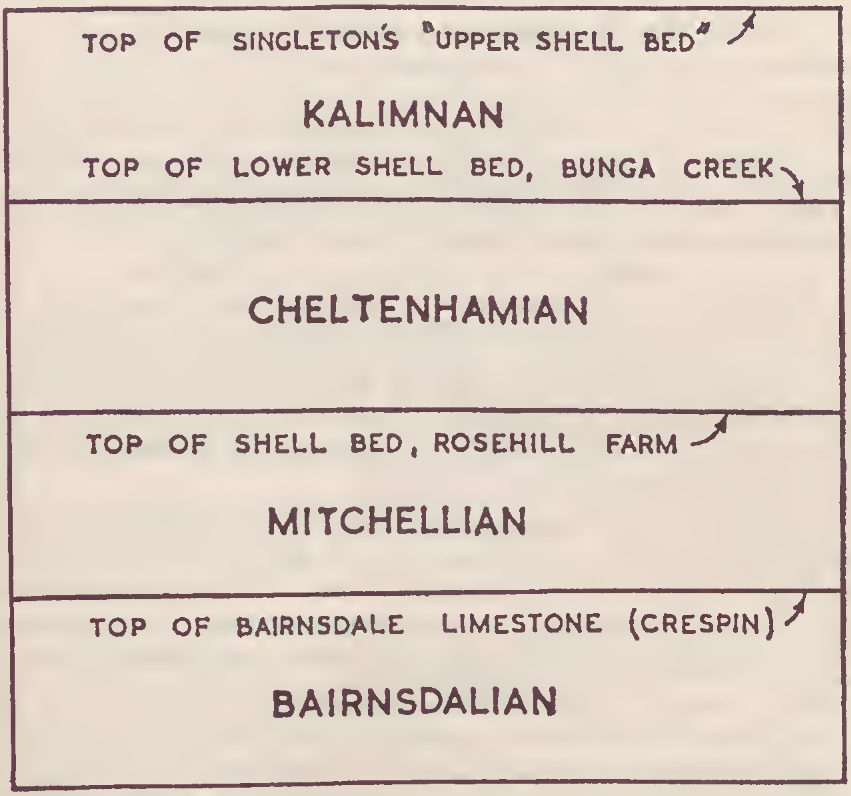


Fig. 2—Diagram showing proposed redefinition of Upper Tertiary local stages.

## Re-definition of the Kalimnan

The top of the Kalimnan stage may be conveniently re-defined by using the fauna of the Upper Shell Bed at Jemmy's Point, the molluscan portion of which is partly listed herein. The foraminifera will be listed in the near future by Dr A. N. Carter. As we have seen, this bed is the precise equivalent of beds (c) and (g) and (h) of Sections 5 and 6 respectively (Bunga Cr.), and probably also the precise equivalent of the shell bed at Nyerimalang.

This means that the overlying marine bed (i) at Jemmy's Point, is post-Kalimnan in age. There is no real advantage in extending the Kalimnan up to include the poor fauna of this bed which would be more in accord with Singleton's definition if not with usage, for whereas non-marine sediments succeed this bed at

Jemmy's Point, a thickness of some 20′ of poorly fossiliferous marine sediments succeed the equivalent bed in the Bunga Cr. road cutting (N. side).

Thus, even if, at the type locality, the Kalimnan was defined to include the fauna of bed (i), there would be post-Kalimnan marine beds in the vicinity so that no useful purpose would be served.

The base of the stage is much more difficult to re-define, for it is not merely a matter of convenient definition, but it is also necessary to consider relationships with the Cheltenhamian and Mitchellian Stages.

## Cheltenhamian Equivalents in the Gippsland Basin

Since the Mitchellian Stage was introduced by Crespin in 1943, two years after Singleton introduced the Cheltenhamian Stage, most workers, both within and outside Australia (David 1950, Withers 1953, Fairbridge 1953, O. P. Singleton 1954, Gill 1957, Glaessner 1959), have felt that in the absence of further evidence the Mitchellian should provisionally be placed in synonomy with the Cheltenhamian. Crespin (1950), however, has maintained her 1943 position, which was that the Cheltenhamian was equivalent to the lower part of the Kalimnan.

Finlay (1947) on certain foraminiferal evidence suggested that there may be a concealed stratigraphic break between the Mitchellian and the Bairnsdalian. If this were so, it would leave open the interesting possibility that the Cheltenhamian is antecedent to the Mitchellian. Ludbrook (1957), working on a very full sequence in the South Australian portion of the Murray Basin, suggested the presence of an unnamed stage between the Cheltenhamian and Bairnsdalian. This possibility is even more interesting for, if the 'unnamed' stage were the Mitchellian, the position would be virtually the same as Crespin (1943).

In the appended molluscan lists the Cheltenhamian fauna is compared with those of the Mitchellian and 'Kalimnan'. It will be observed that in a general way the Cheltenhamian fauna has as much affinity with those of the 'Kalimnan' as with the Mitchellian.

Some of the more significant elements deserve comment. The glycymerids of the Cheltenhamian are decidedly of the 'Kalimnan' type whereas those of the Mitchellian are of the Balcombian-Bairnsdalian type. The *Tylaspira* of the Cheltenhamian is the 'Kalimnan' *coronata*, not the Mitchellian *clathrata*. *Carbula* aff. *coxi* Pilsbry is not present in Mitchellian or older strata as far as the writer has observed, but a related form is recorded from the Cheltenhamian at Beaumaris. The closest approach to *Cucullaea aff. praelonga* from Beaumaris is made by the *Cucullaea* at Mississippi Cr. in the Gippsland Basin sequence. Both *Bankivia* and *Liapyrga*, which at present are not known before the Kalimnan in the Gippsland Basin, occur in the Cheltenhamian. However, the different species of *Liapyrga* involved and the extended range of *L. quadricingulata* in the Murray Basin (Ludbrook 1961) largely vitiates this observation. The *Eucrassatella* from Beaumaris is closer to the 'Kalimnan' *kingicaloides* than to the *Eucrassatella* from the Mitchellian. *Mactra hamiltonensis* is known only from Beaumaris and Pliocene localities.

On the other hand, the strikingly older elements in the Cheltenhamian fauna must not be overlooked. *Aturia australis* deserves a special mention. This older element was commented upon by Hall and Pritchard (1897).

All evidence considered, it seems that the closest approach to the Cheltenhamian fauna is made by that of the lower Bunga Cr. group, but it is probable that an even closer comparison might be made with the unlisted fauna of marker bed C2 which occurs lower in the Kalimnan.

### Problem of the Nodule Bed

It will be recalled that in Singleton's type thickness of sediment at Beaumaris, the phosphatic nodule bed was included. The *Cucullaea* below the nodule bed indicates that the silty sands are of Bairnsdalian age. On the approach developed, this means that the entire thickness of Mitchellian is missing or represented by the 3″ nodule bed. In view of this uncertainty, and also because it is not possible to get an adequate fauna from this bed, it is here suggested that the nodule bed is better removed from the type thickness of sediment. If this is done, however, the period of time represented by the deposition of the 5′ or 6′ of sediment from which the listed fauna was collected would most likely be small, and it is probable that during this time only a small portion of the lower part of the Kalimnan in the Gippsland Basin would be deposited.

Like the Balcombian, which also has its type section on the E. side of Port Phillip Bay, the type section is therefore poor and presents considerable difficulty to the stratigrapher. Furthermore, if, as suggested herein, the Cheltenhamian is represented in Gippsland by some portion of the lower part of the 'Kalimnan', the 'Kalimnan' has clear priority and the Cheltenhamian should lapse into synonomy as Crespin originally suggested.

On the other hand, the Lower 'Kalimnan' has a distinctive molluscan fauna, and it should have stage status. Accordingly, it is suggested, for the criticism of other workers, that the term Cheltenhamian be used for that portion of the Gippsland Basin sequence between the top of the shell bed at Rosehill and the top of the lower shell bed (b) in the Bunga Cr. road cutting (N. side). It is therefore faunally defined by beginning just above the topmost Mitchellian and finishing just above the fauna of the lower shell bed at Bunga Cr. The fauna of Chapman and Crespin's marker bed C2, unlisted at present, low in their Kalimnan, will be, when it is known, a useful central marker for the Cheltenhamian as newly opposed.

The top of the Bairnsdalian and therefore the base of the Mitchellian remains poorly defined on both mollusca and foraminifera (Carter 1959), but it should prove possible to improve the position in the future.

One serious objection which can be made to this analysis is that the correlation suggested may be a correlation of facies rather than time. The writer has shown (Wilkins 1962) that, following the Bairnsdalian, there was a gradual shallowing of waters along the N. boundary of the Gippsland Basin. However, the environmental range over the region of comparison is hardly great enough to markedly affect the attempted correlation, although it would be surprising if facies has not made some contribution.

The Miocene-Pliocene boundary in the Gippsland succession is an entirely different problem and one on which the mollusca have little to contribute. Not only are pelagic foraminifera scarce in the Gippsland Basin (Carter 1959), but pelagic molluscs are correspondingly rare. The present paper records the first finding of the pelagic janthinid *Hartungia* from the Gippsland Basin. The record is based upon a small but definite fragment from the Upper Shell Bed of the Bunga Cr. road cutting (S. side). It is not unreasonable to assume that it belongs to the only Australian species, *H. dennanti* (Tate). The species group to which *Hartungia dennanti* belongs is known only from the Pliocene (Fleming 1953). *Aturia australis*, though not found in the Gippsland Basin, is not uncommon at Beaumaris in the Cheltenhamian. The genus apparently does not range above the Miocene, although it is conceivable that the local species could have lingered on into the Pliocene. Until pelagic foraminifera are better known from this portion of the column, it is probably least confusing to retain the boundary in its customary place, between the Cheltenhamian and Kalimnan, even though they have been re-defined.

## Conclusion

Molluscan evidence and detailed stratigraphy combine to suggest that the Cheltenhamian is equivalent to some part of the Lower Kalimnan as Crespin suggested in 1943. However, because this horizon has a distinctive molluscan assemblage, it is proposed that by suitable re-definition of the stages in the complete Gippsland Basin sequence, all 3 stages, Mitchellian, Cheltenhamian and Kalimnan will become valid and useful. For present convenience it is suggested that the Miocene-Pliocene boundary be continued to be drawn between the Cheltenhamian and Kalimnan.

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## References

Boutakoff, N., 1955. A new approach to the petroleum geology and oil possibilities in Gippsland. *Mining and Geol. Journ. Vict.* 5 (4 & 5) : 39-56.

———, 1958. Lake Wellington Formation, Gippsland. *Ibid.* 6 (2) : 46-9.

Carter, A. N., 1959. Guide foraminifera of the Tertiary stages in Victoria. *Ibid.* 6 (3) : 48-51.

Chapman, F., 1918. On the age of the Bairnsdale Gravels with a note on the included fossil wood. *Proc. Roy. Soc. Vict.* 31 (1) : 166-75.

———, 1926. Geological notes on Neumerella and the section from Bairnsdale to Orbost. *Ibid.* 38 : 125-42.

Chapman, F., and Crespin, I., 1932. The Tertiary geology of East Gippsland, Victoria, as shown in borings and quarry sections. *Palaeont. Bull.* 1. Dept of Home Affairs, Canberra.

Crespin, I., 1943. The stratigraphy of the Tertiary marine rocks in Gippsland, Victoria. *Bur. Min. Resourc. Aust. Bull.* 9 (Mimeo).

———, 1950. Australian Tertiary microfaunas and their relationships to assemblages elsewhere in the Pacific Region. *Jour. Paleontology* 24 (4) : 421-9.

David, T. W. E., 1950. The Geology of the Commonwealth of Australia. Vol. 1. Edward Arnold and Co., London.

Dennant, J., 1891. Notes on the Miocene strata at Jemmy's Point with brief remarks on the Older Tertiary at Bairnsdale. *Proc. Roy. Soc. Vict.* 3 : 53-66.

Dennant, J., and Clark, D., 1898. The Miocene strata of the Gippsland Lakes area. *Ibid.* 10 (2) : 129-39.

———, and ———, 1903. The geology of the valley of the lower Mitchell River. *Ibid.* 16 (1) : 12-47.

Dennant, J., and Kitson, A. E., 1903. Catalogue of the described species of fossils (except bryozoa and foraminifera) in the Cainozoic fauna of Victoria, South Australia and Tasmania. *Rec. Geol. Surv. Vict.* 1 (2) : 89-147.

Emery, K. O., 1950. Contorted Pleistocene strata at Newport Beach, California. *Jour. Sed. Pet.* 20 (2) : 111-15.

Fairbridge, R. W., 1953. Australian Stratigraphy. University of Western Australia Textbooks Board.

Finlay, H. J., 1947. The foraminiferal evidence for Tertiary Trans-Tasman correlation. *Trans. Roy. Soc. N.Z.* 76 (3) : 327-52.

Fleming, C. A., 1953. New evidence for world correlation of marine Pliocene. *Aust. J. Sci.* 15 (4) : 135-6.

Gaskin, A. J., 1943. The geology of Bindi, Victoria. *Proc. Roy. Soc. Vict.* 55 (1) : 81-106.

Gill, E. D., 1957. The stratigraphical occurrence and palaeoecology of some Australian Tertiary Marsupials. *Mem. Nat. Mus. Vict.* 21 : 135-203.

Glaessner, M. F., 1959. Tertiary stratigraphic correlation in the Indo-Pacific Region and Australia. *Jour. Geol. Soc. India* 1 : 53-67.

Hall, T. S., 1897. A contribution to our knowledge of the Tertiaries in the neighbourhood of Melbourne. *Proc. Roy. Soc. Vict.* 9 : 187-229.

———, 1902. A suggested nomenclature for the marine Tertiary deposits of Southern Australia. *Ibid.* 14 (2) : 75-81.

Howitt, A. W., 1874. Notes on the geology of part of the Mitchell River Division of the Gippsland Mining District. *Geol. Surv. Vict. Rept. Prog.* 1 : 59-73.

Ludbrook, N. H., 1954. The molluscan fauna of the Pliocene strata underlying the Adelaide Plains. Pt 1. *Trans. Roy. Soc. S.A.* 77 : 42-64.

———, 1957. A reference column for the Tertiary sediments of the South Australian portion of the Murray Basin. *Jour. Proc. Roy. Soc. N.S.W.* 90 : 174-80.

———, 1961. Stratigraphy of the Murray Basin in South Australia. *Geol. Survey S. Aust. Bull.* 36.

Mines Dept., Victoria, 1938. Records of Boring Operations for Years 1923-30.

Pritchard, G. B., 1892. Remarks on the Tertiaries of Australia. *Ann. Rept. S.A. School of Mines and Industries* for 1891, pp. 171-75.

Singleton, F. A., 1941. The Tertiary geology of Australia. *Proc. Roy. Soc. Vict.* 53 : 1-125.

Singleton, O. P., 1954. The Tertiary stratigraphy of Western Australia—A review. *Proc. Pan. Indian Ocean Sci. Cong., Perth* 1954, Section C. pp. 59-65.

Thomas, D. E., and Baragwanath, W., 1949. Geology of the Brown Coals of Victoria. Pt 1. *Mining and Geol. Jour. Vict.* 3 (6) : 28-55.

Whitehouse, F. W., 1926. The Cretaceous Ammonoidea of eastern Australia. *Mem. Qld. Mus.* 8 (3) : 195-242.

Wilkins, R. W. T., 1962. Stratigraphy, sedimentation and weathering of Tertiary rocks along the northern boundary of the Gippsland Basin. M.Sc. Thesis, University of Melbourne.

Withers, T. H., 1953. Catalogue of Fossil Cirripedia, Vol. III, Tertiary, British Museum, London.

## Appendix—Faunal Lists

Locality 1. Rosehill Farm, Mitchell R.
2. Above the nodule bed, Beaumaris.
3. Bunga Cr., bed (b), Section 6.
4. Mississippi Cr., Tramway Cutting.
5. Meringa Cr. Road Cutting, *c.* 15 ft above S.L.
6. Lower Shell Bed, Jemmy's Point.
7. Upper Shell Bed, Jemmy's Point.
8. Nyerimalang (Cudmore Collection).
9. Bunga Cr., bed (c), Section 5.

| Species | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| *Alocospira orycta* (Tate) | × | × | × | × | × | × | × | × | × |
| *Antephalium muelleri* (Tate) | | × | | | | | | | |
| *Antigona cognata* (Pritchard) | × | × | | × | | | | | |
| *Arcturellina depressulata* (Ch. & Cr.) | | | × | | | × | × | | |
| ——— *gippslandica* (Ch. & Cr.) | | | × | × | × | | | | |
| ——— *solida* (Tate) | | × | | | | | | | |
| ——— sp. nov. | | | × | | × | × | × | × | |
| *Argobuccinium* aff. *bassi* (Angas) | | | × | × | × | × | | | |
| *Astele* sp. nov. | | × | × | | | | | | |
| *Aturia australis* McCoy | | × | | | | | | | |
| ?*Austrosassia* sp. nov. | × | | | | | | | | |
| *Austrotriton* sp. nov. | × | | | | | | | | |
| *Austrovoluta* sp. nov. 1 | | | × | | | | | | |
| ——— sp. nov. 2 | × | | | | | | | | |
| *Bankivia howitti* Pritchard | | | | | | × | × | × | × |
| ——— aff. *fasciata* (Menke) | | × | | | | × | × | × | × |
| *Bassina paucirugata* (Tate) | | | | | | | × | × | × |
| *Cardita kalimnae* Pritchard | | | × | × | × | | | | |
| *Corbula* aff. *coxi* Pilsbry | | × | × | | × | × | × | × | × |
| ——— *ephamilla* Tate | × | × | × | × | × | × | × | × | × |
| *Cucullaea* aff. *praelonga* Singleton | × | × | × | × | | | × | | |
| '*Daphnella*' *granulosa* Ch. & Cr. | | | × | | | | | | |
| *Eglisia* aff. *triplicata* (Tate) | × | × | × | × | × | × | × | × | × |
| *Electromactra howchiniana* (Tate) | | × | | | | | | | |
| *Etrema gippslandensis* Powell | | | × | | | | | | |
| *Eumitra* aff. *alokiza* (T. Woods) | | | × | | × | | | | |
| *Fusus gippslandicus* Tate | | | × | × | × | × | × | | |
| *Gari hamiltonensis* (Tate) | | × | | | | | | | |
| *Gemmaterebra* aff. *catenifera* (Tate) | | | × | × | | | | | |
| ——— *subcatenifera* (Tate) | | | | | × | × | × | × | × |
| *Glans dennanti* (Ch. & Cr.) | | | × | × | | | | | |
| ?——— *spinulosa* (Tate) | | × | | | | | | | |
| ——— aff. *spinulosa* (Tate) | × | | | | | | | | |
| *Glycymeris cainozoica* (T. Woods) | | × | | | | | | | |
| ——— *halli* Pritchard | | × | | | | | | | |
| ——— *paucicostata* Pritchard | | | | | × | × | × | × | × |
| *Hartungia* sp. | | | | | | | | | × |
| *Hauturua exuta* Powell | | | × | | × | | | | |
| *Hina cainozoica* (T. Woods) | × | | | | | | | | |
| *Homalina ralphi* (Finlay) | × | × | × | × | × | × | × | | × |
| *Latirus* aff. *approximans* Tate | | | × | × | × | × | × | | |
| *Leionucula kalimnae* (Singleton) | | × | × | | × | × | × | × | × |
| ——— aff. *kalimnae* (Singleton) | × | | | | | | | | |
| *Limopsis beaumariensis* Chapman | × | × | × | × | | | | | |
| *Liopyrga quadricingulata* Tate | | | | | × | × | × | × | × |
| ——— *sayceana* Tate | | × | | | | | | | |
| *Lissarca* sp. nov. | × | | | | | | | | |
| *Mactra axiniformis* Tate | | | | | | | | × | × |
| ——— *hamiltonesis* Tate | | × | | | | | | × | × |

| Species | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| *Marginella crassidens* Ch. & Cr. | | | × | × | | | | | |
| ———— *hordacea* Tate | | × | | | | | × | | |
| ———— *kalimnae* Ch. & Cr. | | | × | × | | | | | |
| ———— sp. nov. | | | | | | | × | × | |
| *Mauidrillia intumescens* Powell | | | × | | | | | | |
| *Micantapex pritchardi* (Tate) | × | × | × | × | × | × | | | |
| ———— *sayceanus* (Chapman) | × | | × | × | × | | × | × | |
| *Neotrigonia acuticostata* (McCoy) | × | × | × | × | | | | | |
| *Nassarius crassigranosa* (Tate) | | | × | | × | × | × | × | × |
| ———— *sublirella* (Tate) | | | × | | | | | × | |
| *Neotrigonia howitti* (McCoy) | | | | × | × | × | × | × | × |
| ———— aff. *howitti* (McCoy) | | | | | × | | | | |
| *Niso psila* T. Woods | × | | | | | | | | |
| *Notocallista submultistriata* (Tate) | | × | | | × | × | | × | |
| *Olivella nymphalis* (Tate) | × | × | × | × | × | × | × | | × |
| *Ovaleda* aff. *obolella* (Tate) | × | | | | | | | | |
| *Parcanassa* aff. *pauperata* (Lamarck) | | | | | | | × | | |
| *Pervicacia leptospira* (Tate) | | × | | | | | | | |
| *Phos gregsoni* Tate | | | × | × | × | | | | |
| ———— aff. *gregsoni* Tate | × | | | | | | | | |
| ———— aff. *liraecostatus* (T. Woods) | | | × | × | | | | | |
| ———— *tuberculatus* Tate | | | | | | × | × | × | |
| *Placamen subroboratum* (Tate) | | | × | | × | × | × | × | × |
| ———— sp. nov. | × | × | × | × | | | | | |
| *Polinices cunninghamensis* (Harris) | | | × | | | × | × | × | × |
| *Poroleda huttoni* (T. Woods) | | × | | | | | | | |
| *Reticunassa tatei* (T. Woods) | × | | | | | | × | | |
| *Scaeoleda acinaciformis* (Tate) | | × | | | | | | | |
| ———— *crassa* (Hinds) | | | × | | × | × | × | × | × |
| ———— aff. *woodsi* (Tate) | × | × | × | | × | × | × | | × |
| *Sigaretotrema subinfundibulum* (Tate) | × | × | × | | | | | | |
| *Singletonaria lirata* (Tate) | | | × | | × | | | | |
| *Solariella strigata* (T. Woods) | | × | | | | | | | |
| *Sydaphera wannonensis* (Tate) | | | × | | × | × | × | × | × |
| ———— sp. nov. | | | × | | | × | | | |
| *Tawera dennanti* (Ch. & Cr.) | | × | × | × | × | × | × | × | × |
| ———— sp. nov. | × | × | × | × | × | × | × | × | × |
| *Tellina albinelloides* Tate | | | | | | | | × | × |
| ———— aff. *albinelloides* Tate | × | | | | | | | | |
| '*Terebra*' *geniculata* Tate | | × | | | | × | × | | × |
| ———— sp. nov. | | | | | | | × | × | |
| *Tylospira coronata* (Tate) | | × | × | × | × | × | × | × | × |
| ———— *clathrata* (Tate) | × | | | | | | | | |
| *Tomopleura dilectoides* (Ch. & Gab.) | | | | | | × | × | × | × |
| ———— aff. *dilectoides* (Ch. & Gab.) | | × | | | | | | | |
| *Trachycardium gippslandicum* Crespin | | | | × | | | | | |
| '*Trichotropis*' sp. nov. | | | × | × | × | | | | |
| *Tucetilla* aff. *striatularis* (Lamarck) | | × | | | | | | | |
| ———— aff. *tenuicostata* (Reeve) | × | × | × | × | | | | | |
| *Tucetona convexa* (Tate) | | × | | | | | | | |
| ———— aff. *decurrens* (Ch. & Sing.) | | × | × | × | | | | | |
| ———— *gunyoungensis* (Ch. & Sing.) | × | | | | | | | | |
| ———— *subtrigonalis* (Tate) | × | | | | | | | | |
| *Uromitra euglypha* (Tate) | | | × | | × | | | | |
| ———— aff. *terebraeformis* (Tate) | | × | | | × | × | × | | |
| *Vimentum calva* (Tate) | | × | | | | | | | |
| ———— *subcompacta* (Ch. & Cr.) | | | × | × | | | | | |
| *Zemira praecursoria* Tate | | × | | | | | | | |
| *Zenatiopsis angustata* Tate | | | × | × | | | | × | × |